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ANALYSIS OF VIBRATION IN ROTARY EQUIPMENT

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ABSTRACT

Vibration is the study of the oscillatory motion of machines in a dynamic state and its measurement plays an important role in monitoring the machinery. Unbalance, looseness, misalignment and bearing defect are some of the causes of vibration. Our present study includes carrying out vibration analysis on the shaft bearing assembly and cone crusher using ansys software V16.0 and vibration analyzers. Cone crusher is an advanced high power hydraulic crusher in which heavy vibrations persist due to the eccentric sleeve. From the analysis carried out on crusher shaft root causes for vibrations have been identified and necessary modifications were made in the base frame thereby reducing the vibrations by approximately 20%. These results were confirmed by performing spectrum analysis on the base frame.

KEYWORDS: Vibrations, Cone Crusher, Crusher Shaft, Ansys, Natural Frequency, Deformation & Harmonic Response

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Original Article

1. INTRODUCTION

Vibration is the study of the oscillatory motion of machines in a dynamic state. Mass and elasticity are the basic conditions for any system to produce vibrations. Mass is inherent within system and elasticity is due to relative motion between the components of the system. It deals with the effect of vibrations on the performance of machine and safety of systems. Elements that constitute a vibration system are 1) mass 2) spring 3) damper 4) excitation force. Energy stored in the spring is dissipated from the damper in the form of heat. Energy enters the system through the application of an excitation force [1]. An excitation force is applied to the mass (m) of the system. The spring (k) possesses elasticity and is assumed to be of negligible mass. A spring force exists if the spring is deformed, such as the extension or the compression of a coil spring. Therefore the spring force exists only if there is a relative displacement between the two ends of the spring. The damper has neither mass nor elasticity. Damping force exists only if there is relative motion between the two ends of the damper. Energy enters a system by the application of an excitation force. The excitation force varies in accordance with a prescribed function of time. Free vibrations and forced vibrations are the two types of vibrations[4]. The vibration of dynamic systems under the influence of an excitation is called forced vibrations. Forced vibrations occur if a system is continuously driven by an external agency. If no disturbance or excitation is applied after the zero time, the oscillatory motions of the system are called free vibrations.

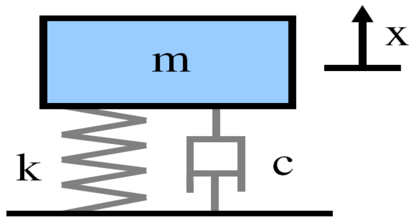


Figure 1: Spring Mass System

Hence the vibrations describe the natural behavior or the natural modes of vibrations of a system. Natural frequency, which is mainly a function of mass, stiffness, and damping of the system from its general solution. Frequency is associated to do with the change in the rate of some variable. Frequency is measured in cycle/sec or hertz (HZ). Fourier transform is a tool to measure the frequency content of a signal [2]. Damping is an influence within or upon the oscillatory system that has the effect of reducing, restricting or preventing its oscillations. In a physical system, damping is produced by processes that dissipate the energy stored in the oscillations. The system returns (exponential decay) to equilibrium without oscillating is called overdamped. The system returns to equilibrium as quickly as possible without oscillating is called critically damped. The system oscillates (at reduced frequency compared to the undamped case) with the amplitude gradually decreasing to zero is called underdamped. The system oscillates at its natural resonant frequency without experiencing decay of its amplitude is called undamped. Resonance occurs when the excitations frequency is equal to the natural frequency of the system. No energy input is needed to maintain the vibrations of a undamped system at its natural frequency. Thus, any energy input will be used to build up the amplitude of the vibration, and the amplitude at resonance of a undamped system will increase without limit. Vibration can result from a number of conditions acting alone or in combination. This may lead to shortened machinery life, poor product outputs and also emergency shutdowns. Vibrations are mainly caused due to unbalance, misalignment, mechanical looseness, aerodynamic forces, bearing defect, material wear, and structural resonance.

2. VIBRATION MEASUREMENT

Vibration measurement provides a very effective way of monitoring the dynamic conditions such as unbalance looseness etc. Vibrations are measured within a specific frequency range. Any vibration has two measurable quantities. Vibration characteristics can be determined by calculating how fast (frequency) and how far (amplitude) the body is moving. So amplitude and frequency are the two measurable quantities of any vibrating body. Vibration amplitude indicates the severity of the problem. Vibration frequency indicates the source of the problem. Acceleration which is a second derivative of displacement and it is a measure of vibration intensity. Acceleration measured at a particular point indicates the total vibratory shock. Vibrations are generally measured in three directions horizontal, vertical, axial. Vibrations are measured using accelerometers, velocity sensors, displacement probes or eddy probes.

3. CONE CRUSHER

Cone crusher is an advanced high power hydraulic crusher which is designed primarily to achieve top performance in fine reduction crushing [3]. It has a very large crushing ratio with high productivity. The crusher has an eccentric sleeve which is driven by the motor. It breaks the rocks by squeezing it between the gyrating spindles. These spindles are fully covered with resistant, mantle and a manganese bowl liner and mantle.

Figure 2: Cone Crusher

Figure 3: Crusher Shaft

Broken pieces of rocks fall down to the next position where it is broken again and the same process continues until the broken pieces become small enough so that it can pass through the narrow opening that is at the bottom. The adjustable gap width can be varied by the hydraulic piston located at the bottom and the upper section of the crusher accommodates wedge-shaped crushing tools. Between the two sections of the crusher, drive is present. Cone Crusher reduces the feed material by application of pressure. A bevel gear with helicoidal tooth ensures a smooth and quiet running of the machine. As there are no bearings at the top it is easy to replace the crushing tools. Design inherent in the crusher avoids material clogging. A hydraulic system provided for gap adjustment also protects against overload. Dust proof sealing is inserted between the supporting conical housing to the eccentric shaft and supporting cone prevent dust penetration.

4. ANALYSIS

This paper focuses on analysis carried out using ansys and vibration analyzers for identifying the problems during the design stage and also while operating the crusher. Modal analysis will be carried out on the machine component to determine its vibration characteristics like natural frequencies and mode shapes. Natural frequencies and mode shapes are very important parameters in transient vibration analysis. Analysis has been carried out on the shaft bearing assembly using ansys software. A simple shaft bearing assembly was designed in cad software to perform vibration analysis. Analysis includes performing both modal and harmonic analysis.

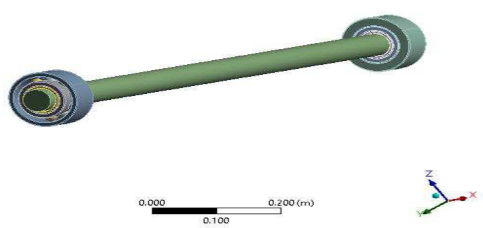


Figure 4: Shaft Bearing Assembly

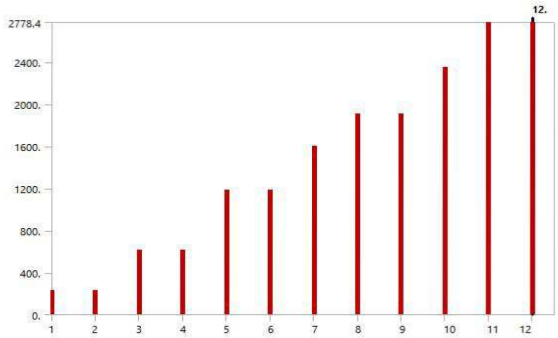
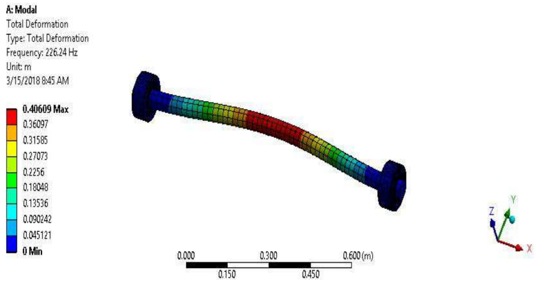


Figure 5: Mode Vs Frequency Chart

Once the drawing is completed geometry is meshed to identify the nodal points. Figure 5 shows a meshed body. The above chart indicates the frequency at each calculated mode. Based on the frequencies calculated at each mode their respective deformations are obtained as shown below. Figure 6 shows one such deformation at mode 1. Similarly, deformations are calculated at each mode.



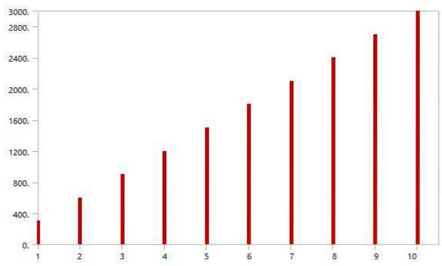
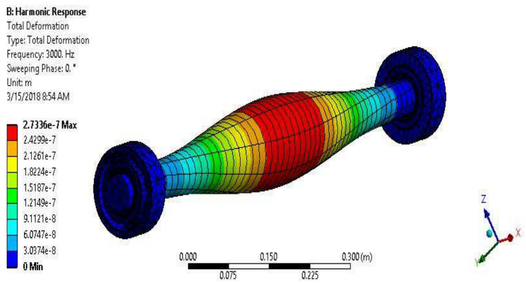


Figure 6: Modal Response at Mode 1 **Figure 7: Mode Vs Frequency**

Harmonic response is a technique to determine the steady-state response of a structure to loads that vary sinusoidally. This analysis helps to predict the sustained dynamic behavior of machine components. This helps the designer to verify whether the proposed design will overcome resonance, fatigue, and other harmful effects of forced vibration [6]. This analysis calculates only steady state forced vibrations and the transient vibrations are not taken into account. Harmonic response analysis is a linear analysis and any nonlinearity such as plasticity etc will be ignored even though they are defined [7]. Analysis includes defining the fixed supports and then setting up the frequency limits i. e. minimum and maximum frequency 0-3000Hz was the defined frequency range. A material used was structural steel.



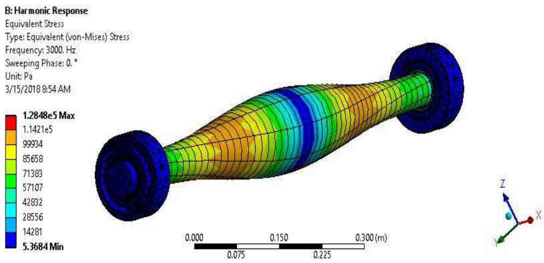
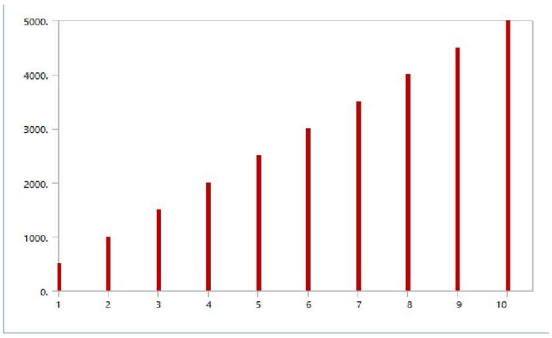


Figure 8: Harmonic Response-Total Deformation **Figure 9: Harmonic Response-Equivalent Stress**



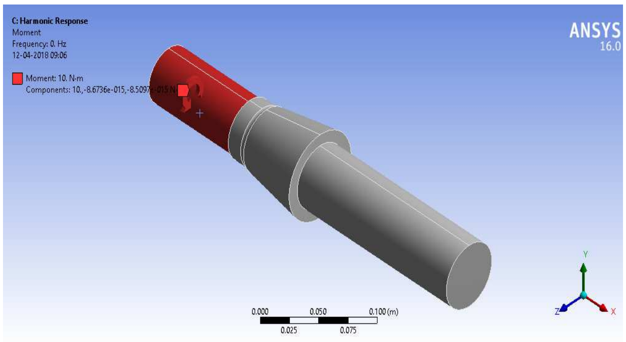


Figure 10: Mode Vs Frequency **Figure 11: Harmonic Response-Moment**

From the above phase angle response, it has been observed that there is a phase shift of 180^0 at 1500Hz. This implies that the root cause for the vibrations was looseness. In the same way, analysis has been carried out on crusher shaft. Once the meshing has been done modal analysis will be carried out on the shaft. Frequencies at their respective mode shapes were given below.

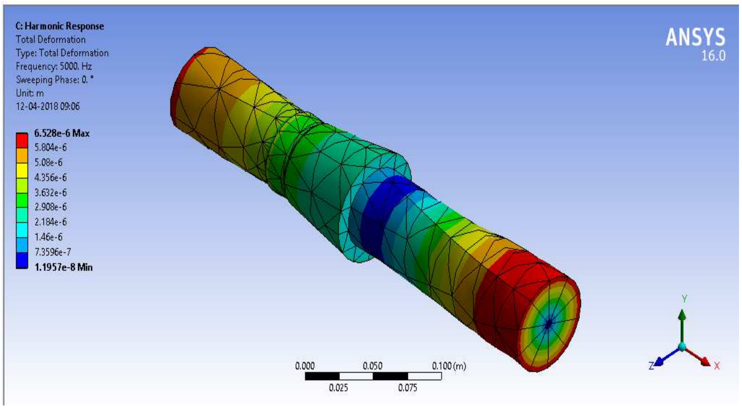


Figure 12: Total Deformation

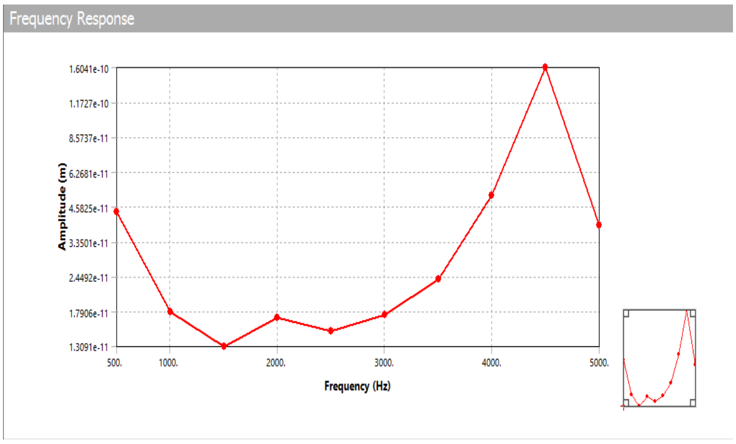


Figure 13: Frequency Response

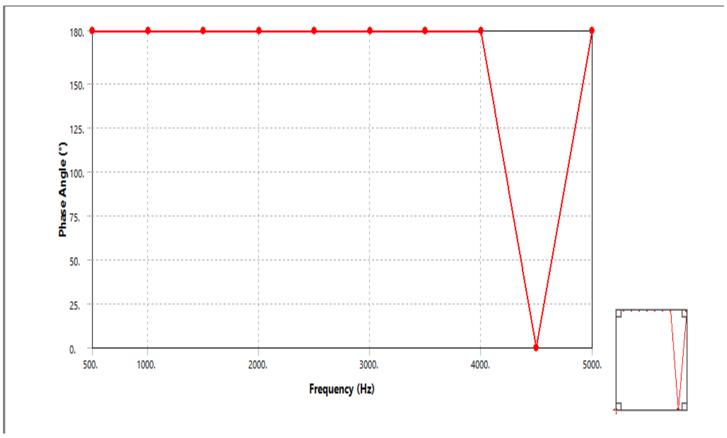


Figure 14: Phase Angle

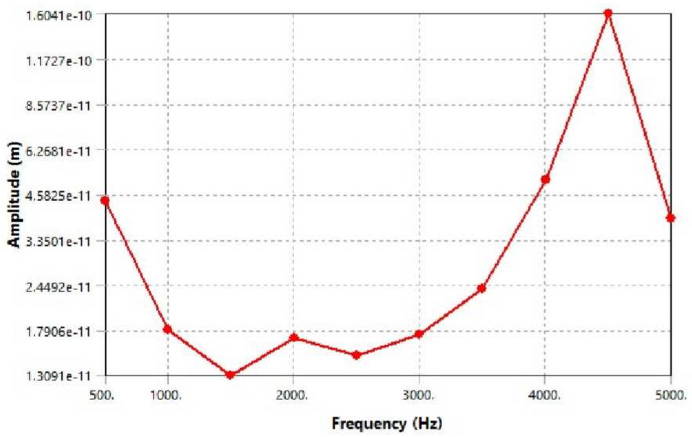


Figure 15: Frequency Vs Amplitude

From the above analysis carried out on crusher shaft, it can be concluded from the frequency response and phase angle analysis the root cause for the problem is bearing defect. Confining to the design requirements the crusher shaft is made to rotate at very low rpm approximately equal to 20 rpm. During the operation of the crusher heavy vibrations were observed. To measure the extent of vibrations spectrum analysis was carried out on the base frame and the results are plotted below. To bring the vibrations to the accepted level some modifications were made in the base frame.

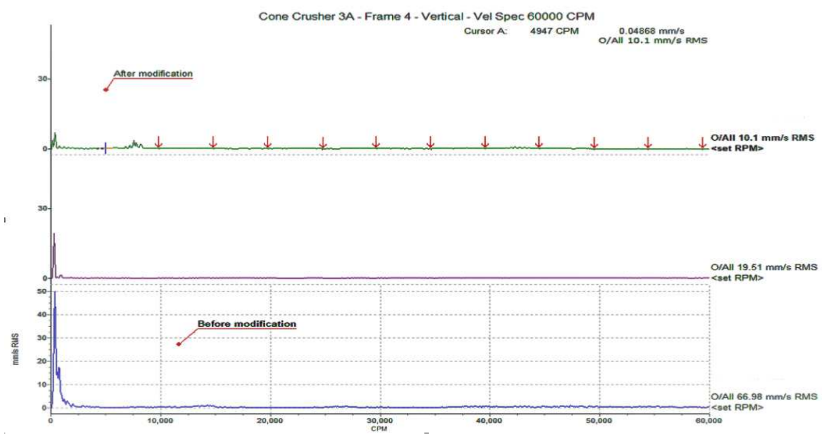
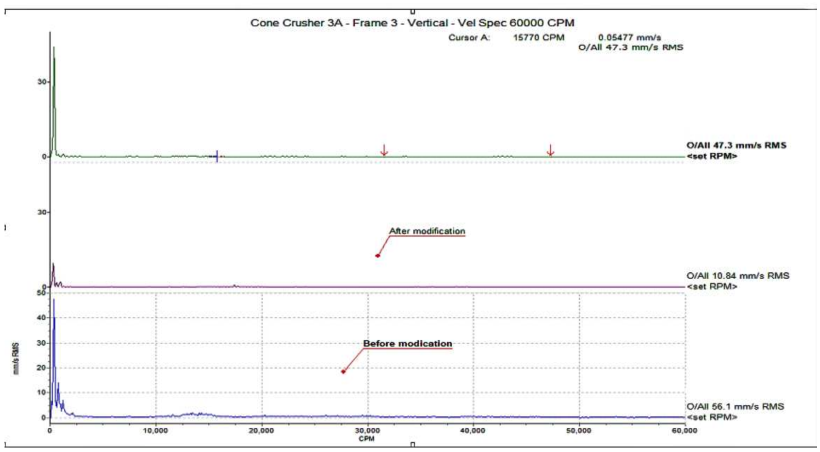


Figure 16



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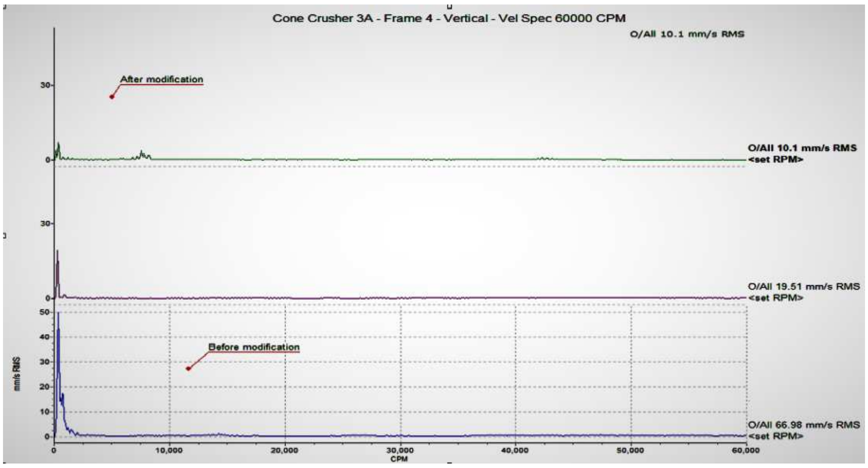

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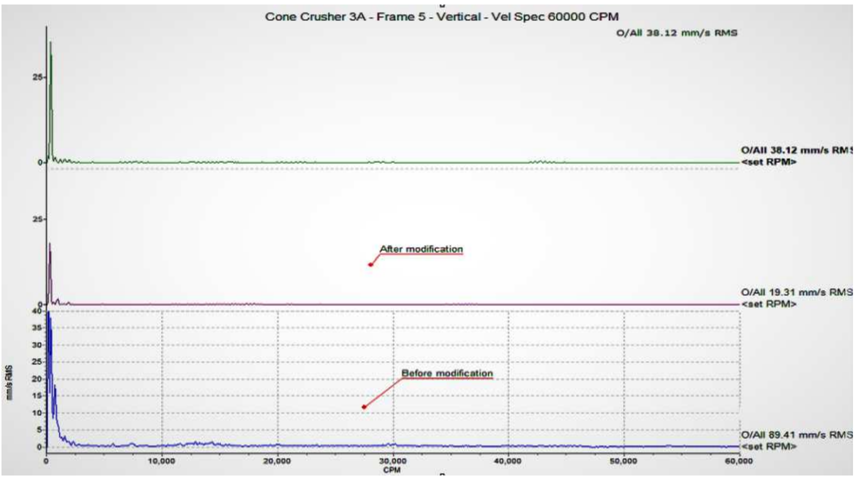

Figure 19

Table 1

	Amplitude Before Modification	Amplitude After Modification
1	66.98	19.51
2	56.1	16.84
3	66.98	19.51
4	89.41	19.31
5	68.51	11.39
6	27.57	15.4
7	33.05	10.96

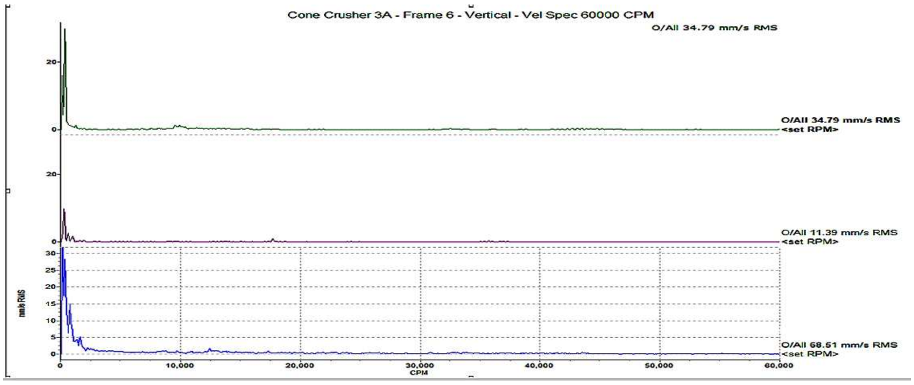

Figure 20

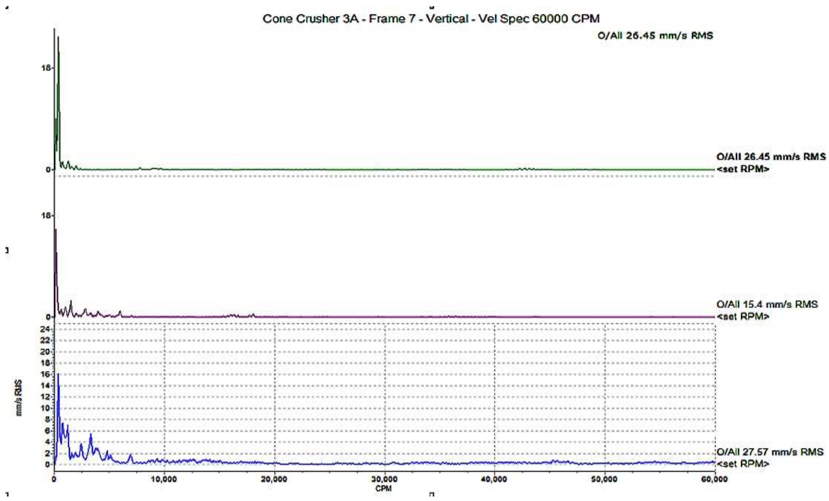

Figure 21

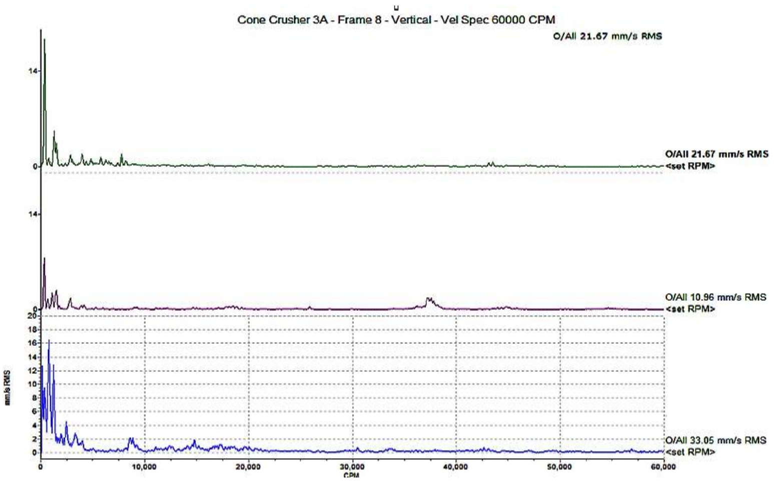

Figure 22

These modifications include adding compensators and stiffeners to the base frame where the frame has lost its rigidity. After these modifications were done again the readings were taken and compared with the previous readings. Vibrations were not reduced completely but were reduced to the acceptable range as mentioned the designer's catalogue. Both the readings were tabulated and compared; approximately vibrations were reduced by 30% as a whole.

5. CONCLUSIONS

Vibration analysis is one of the most important aspects in monitoring the machinery. Ansys plays a crucial role that helps the designer to verify whether the proposed design overcomes resonance, fatigue etc. From the current analysis performed on the shaft bearing assembly and cone crusher root causes for the vibrations were identified and also critical zones that suffer huge deformations were also identified. From the spectrum analysis carried out on the frame, vibrations were measured and then compared with readings that were taken after the necessary modifications were made. As a whole vibrations were reduced by 30%.

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